These included manned interplanetary missions, manned lunar missions, and scientific space-probe missions.

Manned Missions Studied

The manned interplanetary studies, which included estimates of shielding required for solar radiations, indicated that seven man fast Mars and Venus landing missions could be accomplished with orbitally launched nuclear-rocket-powered spacecraft weighing of the order of 1-million lb. Round trips including a 40-day stay at the destination planet could be accomplished in about 400 days, which is about half the time required for a minimum-energy trip. The best chemically rocket powered spacecraft would probably weigh more than 10 times as much as the nuclear system required for these missions.

Studies of manned lunar missions using nuclear-powered upper stages on chemical boosters revealed that the thrust of the chemically powered launch vehicle could be reduced by a factor of 2 or 3 from that needed for all-chemical propulsion. Results of these studies were in good agreement with those made elsewhere (for example, Los Alamos and Marshall Space Flight Center). Following such a course would provide another string to the lunar-program bow, in addition to present effort on chemical rocket "super-boosters" and exploitation of orbital-rendezvous techniques.

Studies of high-energy scientific space-probe missions indicate that nuclear rockets may perform many missions which cannot be done at all with the best multistage chemical systems. For such application, the utility of lightweight nuclear-rocket powerplants of relatively small power output, such as may be attainable with fast reactors or thermal reactors using hydrogeneous moderators, was made apparent. Regardless of the number or type (nuclear or chemical) of stages which are used previous to the last stage, it was found that it always pays to use a lightweight nuclear final stage to achieve the substantial extra velocity increments required for difficult probe missions.

In addition to mission analysis, considerable progress has been made on experimental investigation of a number of fields important to advanced nuclear-propulsion systems. Experimental studies have been made of heat transfer from hot walls to hydrogen with dissociating boundary layers, and to hydrogen at near-cryogenic temperatures, in order to determine correlations of use in these two extreme regimes of interest in nuclear-rocket reactors. Analytical work on hydrogen-cooled and heated nozzles was also undertaken with the aim of finding optimum techniques for the design of rocket-engine nozzles for use with this peculiar fluid. Design criteria so derived have been checked by experimental work. In the turbopump field, experimental study has been continued of the problems of pumping cryogenic hydrogen and of hydrogen-gas-driven turbines. This work will provide a basic understanding of problems and processes encountered in hydrogen turbopump systems as well as a fund of information and data directly useful for design. Fluid-dynamic work in progress during the year included experimental study of flow stability for two-phase and supercritical flow of cryogenic fluids in multiple parallel passages, and air-bromine studies of phenomena in flow of coaxial gas streams.

Anticipating the future, activity at the NASA Lewis Research Center, pioneer in aircraft and rocket research, will continue and expand on nuclear propulsion as that field itself grows.

NUCLEAR RAMJET PROPULSION

By T. C. Merkle

The past year has indeed seen considerable progress in the program to demonstrate the feasibility of using a nuclear reactor as a heat source for ramjet-missile applications. Basically, three areas of work are critical in this program:

1. The production of a nuclear system using an acceptable amount of critical material and having a suitably controlled power distribution. In this area, it was also necessary to prove out a nuclear-control system which could realistically meet the dynamic-response characteristics of a flying machine. The successful demonstration of the Tory II-A-1 test reactor indicates the progress made in these areas.

2. The production of adequate fuel elements for the ramjet application is naturally a key problem. Since the degree of success in this area is a classified matter, progress in this area must remain shrouded in mystery.

3. A third critical area has to do with the engineering design of a reactor having suitable structural properties. Again, the operation of the Tory II-A-1 test reactor without any difficulties indicates that progress has been made, but the precise degree of such progress is again classified information.

During 1961, four reactor tests were conducted, all with the same reactor, Tory II-A-1, shown on page 128. These were run on May 14, September 28, October 5, and October 6, 1961. In all tests the power level was above 40 megawatts, the core temperature greater than 2000 F, and the operating time longer than 45 sec. In the May 14 test the air-flow rate through the reactor was 120 lb/sec.

Future plans revolve around the testing of Tory II-C, a ground-test version of a flyable nuclear reactor ramjet. Tory II-C reactor design is continuing, and reactor parts are presently being fabricated. At the NTS, construction work is in progress to increase the (reactor coolant) air supply from its present capacity of 120,000 lb to 1-million lb; this will allow test operations of increased duration and/or power level. Although projected reactor test schedules remain classified, prospects do seem bright for the development on a useful time scale of a flyable reactor configuration. ♦♦

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